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Obituary

PROFESSOR DAVID BODIAN, M.D., Ph.D.

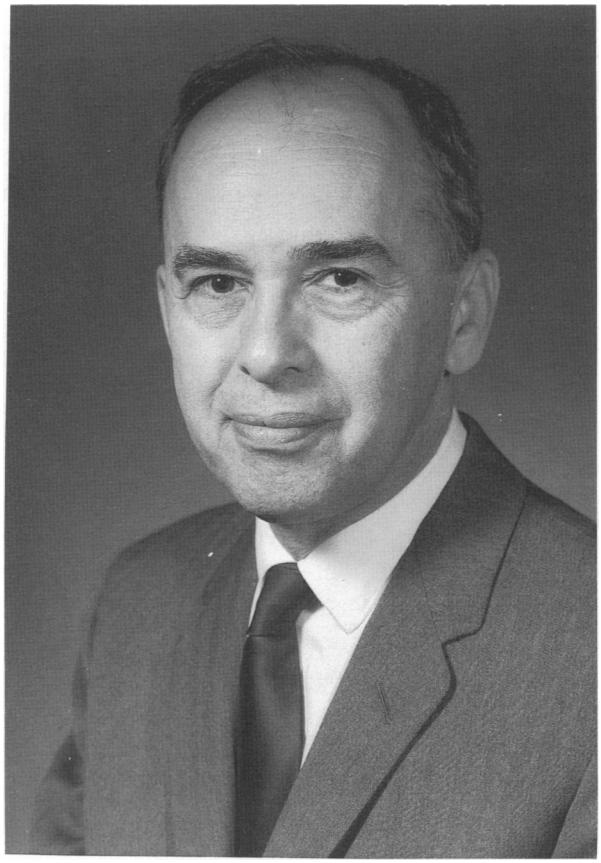
(15 May 1910–18 September 1992)

When David Bodian came to the School of Medicine at Western Reserve University (now Case-Western Reserve) in Cleveland, Ohio, in 1940, to teach neuroanatomy and gross anatomy, he was already a famous scientist. Although only 30 years old, he had invented an important and widely used method for silver staining of nerve fibres in paraffin sections, and had published classic studies on the visual pathways in the Virginia opossum, the structure of synapses in the goldfish brain, and the nature of the infection and spread of the poliomyelitis virus within the primate nervous system. These studies established the themes of the rest of his long and productive academic career in anatomy and neurobiology.

David Bodian was born on 15 May 1910 in St Louis, Missouri, to a family of recently immigrated Ukrainian Jews. He was the first child of the family to be born in America, the oldest son, and the third of 6 children. When he was 3 years old, the family moved to Chicago, Illinois, and there he received his entire formal education, first in the public schools and then at the University of Chicago, where he obtained the degree of Bachelor of Science in Zoology in 1931, the Ph.D. in Anatomy in 1934, and the M.D. in 1937. The family was poor and the father, having failed financially, died in 1929. They were supported largely by the efforts of the 2 elder sisters, who encouraged their siblings to complete their education.

At this time, the Department of Zoology at the University of Chicago was filled with stellar biologists, Frank R. Lillie, Sewall Wright, Alfred Emerson, G. M. Child, Paul Weiss, Benjamin Willier, and Carl R. Moore, among them. In the Medical School, the Department of Anatomy (next door to the Zoology Department) was equally populated with giants such as R. R. Bensley, George W. Bartelmez, Charles Judson Herrick, William Bloom, A. A. Maximow, and Normand Hoerr. During Bodian's days in the Medical School, notable visiting research fellows were J. Z. Young, and Ernst and Berta Scharrer. Karl Lashley was in the Psychology Department along with Heinrich Klüver and Stephen Polyak; Percival Bailey, Paul Bucy, and Douglas Buchanan were in the Department of Neurology and Neurosurgery. In his autobiographical notes for the National Academy of Sciences of the USA, Dr Bodian recorded that he had been taught how to do a lumbar puncture by A. Earl Walker, who was a junior member of the neurosurgery staff.

In college Bodian was considerably impressed with Carl Moore and Benjamin Willier, who introduced him to the study of embryology and the 'magic of experimental approaches to problem solving'. On completing his undergraduate studies, he enrolled in the Medical School, supported by a modest scholarship. He had already studied gross anatomy as an undergraduate and he did so well in neuroanatomy that he was asked to assist in the course the following year. The stipends earned in this way permitted him to stay in school until the completion of his Ph.D. and M.D. degrees. But at the end of his second year in medical school his funds ran out and, obtaining a Wilder Fellowship in Neurology, he enrolled as a graduate student for the Ph.D. degree in Anatomy. Although he was officially under the supervision of C. J. Herrick, his thesis problem – the architecture



and projections of the visual pathways in the opossum – was suggested by Normand Hoerr, and it was he who instructed him in the necessary techniques. In a short time, however, Bodian came under the spell of George Bartelmez, who became his mentor in microscopy and the histology of the nervous system. In order to explore the connections of the optic pathways in the opossum, Bodian required, for his valuable experimental material, a more reliable nerve fibre stain than the methods then available. Bartelmez had been using a silver proteinate known as 'Protargol', manufactured by the Bayer Company in Germany, as a source of silver in the Rogers method. In this stain, silver hydroxide was used to develop the silver previously combined with nerve fibres. Bodian found that the method frequently failed and he turned to organic photographic developers, as Cajal had done before him. As the paraffin sections of whole opossum brain were mounted on $3\frac{1}{4} \times 4$ inch slides, he had constructed a special brass rack to carry the slides through the staining procedures. In order to test whether the copper in the brass holder would interfere with the silver stain, he added a clean penny to the Protargol bath. To his surprise he found that the nerve fibre staining after development and gold toning was superior to any that he had obtained with Protargol alone. Thus the Bodian method was born.

Bartelmez and Hoerr had conducted seminal studies on the synapses on the Mauthner cell in the catfish, which were published in 1933. Their method stained the giant club endings, but failed to reveal other synapses on this cell. Bodian applied his new method to the goldfish brain and discovered a variety of large and small synaptic terminals on the dendrites and cell body of the Mauthner cell as well as on other nerve cells in the medulla. The paper describing his results and emphasising the value of fixation of the nervous system by vascular perfusion with Zenker's fluid was published in the Journal of Comparative Neurology in 1937. His analysis of the structure of these synapses became the basis of an influential review published in Physiological Reviews in 1942, and another in the Cold Spring Harbor Symposium volume on the Synapse in 1952. By virtue of the delicate staining obtained with his method, Bodian was able to provide definitive evidence that the neurofibrillae in the presynaptic ending did not cross the synaptic junction into the postsynaptic dendrite or cell body. At the interface between the synaptic partners, Bodian found a dense membrane, which he called the 'synaptolemma', separating them. Until the advent of electron microscopy in 1954, this was the most perceptive description of the morphology of the synapse.

After qualifying for his medical degree, he determined to pursue a career in research. Instead of going on to an internship in a hospital, in 1938 he went to the University of Michigan as a National Research Council Fellow under the supervision of Elizabeth Crosby, who had also been a student of C. J. Herrick two decades earlier. There he continued his study of the diencephalon of the opossum, but the intellectual climate was not as stimulating as it had been in Chicago, and he cast about for other employment to follow his fellowship. In the fall of 1938, he was offered the position of Fellow in the Department of Anatomy at the Johns Hopkins University School of Medicine in order to join Howard A. Howe, who had established a laboratory there for the study of poliomyelitis in monkeys and humans. Before Bodian moved to Baltimore, Howe sent him sections of monkey brains during the winter of 1939, which he examined while completing his work on the opossum. But early in April, Lewis Weed, the head of Anatomy and the dean of the School of Medicine at the Johns Hopkins, requested that he should take charge of the laboratory immediately, as Dr Howe had suddenly undergone surgery for a perforated peptic ulcer. Bodian quickly received permission to resign from his fellowship with Dr Crosby and proceeded to Baltimore. Thus began 'the most challenging and exciting period in [his] professional life'.

For the next 2 decades he was almost completely occupied with research on poliomyelitis. This work resulted in 3 important discoveries. (1) The virus multiplied within nerve cells in the brain as well as in the spinal cord and spread primarily within nerve fibres to produce the pattern of lesions characteristic of the disease. (2) The virus did not gain entry into the nervous system by way of the olfactory nerves (a popular hypothesis of the time), but by way of the alimentary tract. (3) Certain regions of the brain were resistant to the virus, even when directly injected, and certain susceptible regions (e.g. the spinal cord) could be made resistant by severing the axons of the susceptible nerve cells. This work was interrupted when the sponsoring agency decided to discontinue its funding. Normand Hoerr, who had meanwhile become Chairman of Anatomy at Western Reserve University School of Medicine, offered him an appointment as Assistant Professor of Anatomy, and Bodian moved to Cleveland (1940–41) for a concentrated stint of teaching neuroanatomy while continuing his collaboration with Howe on writing and publishing their joint work. (The present writer was a 1st-year medical student in one of these classes.)

Early in 1942, Howe's laboratory received renewed funding from the National Foundation for Infantile Paralysis, and Bodian returned to Johns Hopkins permanently, first as an Associate in Epidemiology, advancing to Associate Professor in 1946, and then becoming Bayard Halsted Professor of Anatomy and Director of the Department in 1957.

During the period from 1942 to 1957, Bodian and his colleagues (particularly Howard Howe and Isabel Morgan) succeeded in showing that although the poliovirus produced highly variable pathological states, it appeared in no more than 3 immunological types, which had been stable over many years. Basing their thinking on reports in the previous literature that patients with poliomyelitis already had virus-neutralising antibody in their blood at the time of admission to hospital and that newly diagnosed patients only rarely showed detectable virus in their bloodstream at the time of admission, Bodian and his colleagues reasoned that the failure to find virus in the blood in the vast majority of the patients was due to the fact that the bloods were collected after serum antibodies had neutralised the virus present in an earlier, presymptomatic stage of the infection. They confirmed this hypothesis by examining a large series of blood samples collected from an earlier experiment on cynomolgus monkeys that had shown that very small amounts of antibody would prevent the development of paralytic poliomyelitis in that species. The demonstration of a viraemic stage in the infection was accompanied by an equally important discovery that serum antibody levels too small to prevent spread of the virus by nerve fibres were still capable of preventing invasion of the nervous system from the gut. These seminal findings were soon confirmed in other laboratories and in human beings, and they (along with the concurrent success in cultivating the poliovirus in cultures of non-nervous tissue by John F. Enders and his team, in 1949) led directly to the development of practical vaccines against infection with poliomyelitis virus and to the prevention of a catastrophic plague that had terrified people around the world.

As a result of his extensive experience with the neuroanatomical lesions of poliomyelitis, Bodian was called upon to serve on numerous committees of the National Foundation for Infantile Paralysis, the National Institutes of Health, and the Division of Biological Standards. His was an influential voice in the committees on live virus safety testing and in the investigation of the failure of inactivation of formalinized virus vaccine (the notorious Cutter incident). He served as the managing editor of the American Journal of Hygiene (later renamed the Journal of Epidemiology) from 1947 to 1957. In later years he served on the Editorial Boards of Virology (1957–60), Experimental Neurology (1971–75), Anatomical Record (1968–72) and the Journal of Comparative Neurology (1966–73).

During his years of concentration on the poliomyelitis virus, Bodian maintained his research on the morphology and physiology of the nervous system. Among the resulting publications were a classic study (with R. C. Mellors, 1945) of chromatolysis in large motor neurons of the spinal cord in monkeys, the review of synaptic structure of 1942 mentioned above, the rediscovery of nodes of Ranvier in the central nervous system (1951), and the epochal structural analysis of the neurohypophysis of the opossum (1951). This last paper made sense out of the confusing architecture of the posterior lobe of the pituitary gland, showing clearly that the nerve fibres of the hypothalamohypophysial tract ended freely along the vessels of the pituitary in a lobular pattern, unfolded in the opossum but complicated in other vertebrates.

After becoming Professor of Anatomy, Bodian devoted himself increasingly to electron microscopic research on the fine structure and development of the spinal cord. He was among the first to recognise the different shapes of synaptic vesicles that appear in tissues fixed with aldehydes under different conditions, and he pointed out a suggestive relationship between the distribution of ribosomes in nerve cells and the synaptic junctions on their surface. In 1977 he became Professor Emeritus of Anatomy and accepted an appointment as Professor of Neurobiology in the Department of Otolaryngology at the Johns Hopkins University. In this latter capacity he maintained an electron microscopy laboratory and carried out research on the fine structure of the organ of Corti.

David Bodian was accorded many honours during his long career. He was elected a member of the National Academy of Sciences of the USA in 1958, a fellow of the American Academy of Arts and Sciences in 1968, and a member of the American Philosophical Society in 1973. He was President of the American Association of Anatomists for the year 1971–72. In 1957, he was honoured for his work on poliomyelitis by being elected to the Poliomyelitis Hall of Fame of the Georgia Warm Springs Foundation, and in 1985 he received the Karl Spencer Lashley Award from the American Philosophical Society. In 1987, he was awarded an honorary doctorate from the Johns Hopkins University. He was an honorary member of the Anatomical Society of Great Britain and Ireland,

the Société Française de Neurologie, and the Mexican Society of Anatomy.

Dr Bodian was a gentle and modest man. Although always retaining his outward composure and projecting an abiding sense of equanimity, he was capable of great sensitivity to other people and a deep appreciation of the arts. During the last decade of his life he patiently suffered from the effects of Parkinson's disease. He died on 18 September 1992. He is survived by his wife of 48 years, Elinor Widmont Bodian, and five children.

SANFORD L. PALAY